अच्युतमतानुसारिणी

राशिगोलस्फुटानीतिः

TRUE LONGITUDE COMPUTATION ON THE SPHERE OF ZODIAC

ACCORDING TO

ACYUTA

Critically edited with
Introduction, Translation and Appendices
By
K. V. SARMA
Acting Director, V.V.B.I.S. & I.S.
Panjab University, Hoshiarpur

VISHVESHVARANAND VISHVA BANDHU INSTITUTE
OF SANSKRIT AND INDOLOGICAL STUDIES
PANJAB UNIVERSITY
HOSHIARPUR

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1977

प्रथमं संस्करणम्, २०३४ (वि.)

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CONTENTS

INTRODUCTION

The *Rāśigolasphuṭānīti* is a highly interesting work on Indian astronomy, which sets out the views of Acyuta Piṣāraṭi, a versatile Kerala scholar, on a very pertinent point in celestial measurements, *viz.*, whether the longitudes of planets and stars are to be measured along the ecliptic (*Apakrama* or *Krānti-vṛtta*) or each along its own path (*Vikṣepa-vṛtta*).

Manuscript material

A. Two manuscripts of this work have been identified. One, designated A, I came across by chance while examining a composite codex (No. Mal. D. 339) in the Govt. Oriental Mss. Library, Madras. catalogued under the general title of *Parahita-dṛksiddha-gaṇitam*, and copied from an original Malayalam palmleaf manuscript from Kerala. This codex contains several works, some complete and some incomplete, some in Sanskrit and some in Malayalam. The present work occurs on pages 90 to 95. There is no title nor colophon. The beginning bears the usual invocation found in Kerala manuscripts, हरिः श्रीः गणपतये नमः, and at the end, the closing sign श्रीः. The text preserved is generally pure ; the few lapses of the scribe can easily be corrected. Lacunae of a few letters occur in two or three places ; these have been tentatively filled in. Corrections and emendations are shown in footnotes.

B. The second manuscript, again, was the result of a chance discovery, made while examining a composite palmleaf codex in Malayalam script, deposited in the Kerala University Oriental Res. Institute and Mss. Library, Trivandrum, (No. 755), and catalogued under a general title *Gaṇitayuktayaḥ*, on the basis of the first work contained in the codex. The present work occurs as the seventh (G) in the codex and is inscribed in thirteen leaves, numbered 1 to 13. The writing is clear and generally free from errors. The manuscript is not dated, nor any scribe mentioned. It commences with the scribal benediction : हरिः श्रीः गणपतये नमः । अविघ्नमस्तु ।

The textual verses in this manuscript ends with verse 51 and does not extend further. However, it contains, in continuation, an elaborate discussion on verse 51, which is edited below as Appendix I.

Acyuta, the astronomer

Acyuta is generally known in Kerala as Tṛkkaṇṭiyūr Acyuta Piṣāraṭi, Tṛ-k-kaṇṭiyūr (Kuṇḍapura in Sanskrit), near Tirur in South Malabar, being his native place, and Piṣāraṭi, the name of his caste, being the term for one of the external functionaries in a Kerala temple. Acyuta was a profound scholar in grammar and astronomy. He was a pupil of Jyeṣṭhadeva[1] and was patronised by King Ravi Varma of Veṭṭattunāḍ (Skt. Prakāśa-viṣaya),[2] a small principality situated in the present north-eastern part of the Ponnani Taluk of South Malabar. Poet Vāsudeva, in his *Bhṛṅgasandeśa,* pays high tribute to Acyuta's reputation as an astronomer,[3] while Nārāyaṇa Bhaṭṭatiri who learnt grammar from Acyuta, speaks of his teacher's proficiency not only in astronomy and grammar but also in medicine and poetics.[4]

Acyuta's greatness is enhanced by long lines of disciples. One of these starts from his pupil in grammar, Melputtūr Nārāyaṇa Bhaṭṭatiri, one of the greatest of Kerala poets and the author of *Prakriyāsarvasva* and numerous other works. Another line of disciples carried the tradition of his teachings in the subject of *jyotiṣa* to comparatively recent times. To this belonged Tṛppāṇikkara Poduvāḷ,

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1. *Cf.* the concluding verse of his *Uparāga-kriyākrama* :

   प्रोक्तः प्रवयसो ध्यानाद् ज्येष्ठदेवस्य सद्गुरोः ।
   विच्युताशेषदोषेणेत्यच्युतेन क्रियाक्रमः ॥

2. The reference to this King occurs in two of Acyuta's works, *viz., Sphuṭanirṇaya* and *Praveśaka.*

3. *Cf.* : तस्मात् प्रत्यक्प्रहितनयनः कुण्डगेहाधिवासं
   सर्वज्ञं तं प्रणम गिरिशं भक्तिमानच्युतं च ।
   एकस्तावद् वहति शिरसि ज्योतिषामेकमिन्दुं
   ज्योतिश्चक्रं निखिलमपरो धारयत्यन्तरङ्गे ॥

   Bhṛṅgasandeśa, Trivandrum Skt. Ser., No. 128, p. 17.

4. *Cf.* Bhaṭṭatiri's obituary verse on his teacher :

   भ्रातर्ज्योतिषतन्त्र ! पर्यवसिता तिथ्यर्क्षयोस्ते कथा
   धाष्ट्र्यैकप्रवणासि वैद्यसरणे ! नष्टोऽस्यलङ्कार भोः ।
   हे शब्दागम ! निर्दयं विबुधतालुब्धैर्निपीडिष्यसे
   'विद्यात्मा स्वरसर्प'दत्रभवतामाधारभूरच्युतः ॥

Nāvāyikkuḷattu Āzhāti, Pulimukhattu Poṭṭi and Neḍumpayil Kṛṣṇan Āśān, each prominent during his own time.[5] It can aptly be said of Acyuta, शिष्यप्रद्धियंशसे गुरूणाम् 'The fame of the pupils accrues to the glory of the teacher'.

Date of Acyuta

The date of birth of Acyuta should be *circa* 1550 since his famous pupil Melputtūr Nārāyaṇa Bhaṭṭatiri was born in 1560, (*vide* S. Venkitasubramonia Iyer, *Nārāyaṇa Bhaṭṭa's Prakriyāsarvasva*, Trivandrum, 1972, pp. 22-23). The date of Acyuta's death is given by the Kali date विद्यात्मा स्वरसर्वत् (17,24,514, which works out to be A.D. 1621) in his obituary verse भ्रातज्योतिषतन्त्र etc. composed by Nārāyaṇa Bhaṭṭatiri.

Known works of Acyuta

Praveśaka, an illustrative treatise on grammar intended for beginners, is the only known work of Acyuta on this subject.[6] Acyuta's works on astronomy are : *Sphuṭanirṇaya-Tantra* with auto-commentary, an erudite work in six chapters on the correct computation of the planets,[7] *Chāyāṣṭaka*, on the determination of the gnomonic shadow cast by the Moon ;[8] *Karaṇottama*, a manual in five chapters with auto-commentary ;[9] *Uparāga-kriyākrama*, in four chapters, on the computation of lunar and solar eclipses ; *Horāsāroccaya*, which is an adaptation in seven chapters of Śrīpati's *Jātakapaddhati* ; and a Malayalam commentary on the *Veṇvāroha* of Mādhava of Saṅgamagrāma,

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5. On these see K. V. Sarma, 'Direct lines of astronomical tradition in Kerala', *Charudeva Shastri Felicitation Volume*, Delhi, 1973, pp. 601-4.

6. Ed. with the commentary of P. S. Anantanaryana Sastri, *Cochin Sanskrit Series*, No. 2, Trippunithura, 1938.

7. Cr. ed. with Intro. and 10 Appendices, by K. V. Sarma, Hoshiarpur, 1974.

8. Cr. ed. by K.V. Sarma, as Appendix 10 to the edition of *Sphuṭanirṇaya*.

9. Ed. by K. Raghavan Pillai, *Trivandrum Skt. Ser.*, No. 213, 1964.

an early reputed Kerala astronomer generally styled as *Golavid* by later writers. Acyuta wrote this last commentary at the instance of Netranārāyaṇa (in Malayalam : Āzhvāñceri Tamprākkaḷ), the spiritual head of the Nampūtiri Brahmans.[10]

Rāśigolasphuṭānīti

As observed before, the *Rāśigolasphuṭānīti* concerns itself with a detailed discussion on the measurement of the longitudes of celestial bodies in the 'Sphere of Zodiac', the *Rāśigola*. What is meant by *Rāśigola* may be briefly stated here.

The Rāśigola

Indian astronomers envisage the celestial globe from three points of view. In the first case it is called the 'Sphere of Space' (*Khagola*). Here the position of the observer is the centre, the horizon around him is the horizontal great circle, and the *Sama-maṇḍala* (Prime vertical) and *Dakṣiṇottara-vṛtta* (Celestial meridian) are the other two great circles. Obviously, the *Khagola* differs from place to place and from moment to moment, with the result that the Alt-Azimuth co-ordinates of a star which is measured on the fundamental circles of this sphere are also constantly changing. The second conception is that of the 'Atmospheric sphere' (*Vāyugola*) based on the path of the apparent motion of the stars. The basic great circles in this case are : the *Ghaṭikā-vṛtta* or *Viṣuvan-maṇḍala* (Celestial Equator) which is the apparent path of a star which rises exactly in the East ; the *Unmaṇḍala* or *Laṅkā-kṣitija*, the great circle passing through the Celestial Poles at 90° to the Celestial Equator ; and the *Dakṣiṇottara-vṛtta* 90° from the Equinoxes, called the Solstitial Colure. The position of a star with reference to the *Vāyugola* with right ascension-declination co-ordinates changes in course of time due to the *ayana-calana* (the precession of the equinoxes). These two systems are not therefore used in Indian astronomy to denote the positions of celestial bodies.

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10. *Cf.* the concluding verse of the commentary :

माधवन् तान् चमच्चुकळ वेण्वारोहत्तिनच्युतन् ।
– भाषाव्याख्यानमुण्टाक्कि नेत्रनारायणाज्ञया ॥

Cr. ed. K.V. Sarma, Sanskrit College, Trippunithura, 1956.

A third conception is the 'Sphere of Zodiac' (*Rāśigola*), with the *Apakrama* or *Krānti-maṇḍala* (Ecliptic) which is the path along which the Sun apparently moves through the *nakṣatras* (Asterisms), as the prime great circle. A particular point on the *Apakrama-maṇḍala* just to the east of *Revatī* (Zeta Piscium) called *Meṣādi* (First point of *Meṣa*) is taken as the starting point and twelve equal divisions called *Rāśis*, 30° each, are marked on the ecliptic ; great circles perpendicular to the ecliptic are drawn from these points and extended on either side along the celestial sphere to meet at two points on the North and South, each called a *Rāśi-kūṭa* or *Kadamba*. These twelve circles are called *Rāśikūṭa-vṛttas*. This conception of the celestial globe is known as *Rāśigola* or *Bhagola*. Measurements with reference to this sphere are the most constant of the three.

Now, the Sun moves exactly along the *Apakrama-maṇḍala* (ecliptic) while the other planets move along great circles called *Vikṣepa-vṛttas* or *Vimaṇḍalas*, slightly deviating from it. The path of each planet will thus cut that of the Sun at two places, the Ascending Node and the Descending Node, called in Indian parlance the *Pātas*. The *Pātas* of the Moon's path are specially termed *Rāhu* and *Ketu*. The perpendicular distance between the *Apakrama-maṇḍala* and the position of a planet in its *Vikṣepa-vṛtta*, North or South of it, is termed the *Vikṣepa* (latitude) of the planet at that position.

Reduction to the Ecliptic

The position of all planets is denoted in Indian astronomy in terms of two co-ordinates, the longitude which is measured along the *Apakrama-maṇḍala* from the said *Meṣādi*, and *Vikṣepa* (latitude) perpendicular to it. A very pertinent question arises here as to why the measurements of all planets should be made along the Sun's orbit and whether it would not be more reasonable that each planet be measured along its own orbit. This question is dealt with in the work with particular reference to the Moon at the time of an eclipse and, after a detailed refutation of the second view (*vv*. 24*b*-41), it concludes that all measurements of longitude are to be made along the ecliptic and thatt he measurements of the latitude are to be made perpendicular to the ecliptic (*v*. 42).

The work then takes up the question of a correction necessary to the orbital longitude of the Moon to reduce it to the ecliptic, in view of the fact that the Moon actually moves along its orbit but its

longitude is to be measured along the ecliptic. This correction which, in a restricted sense, may be expressed by the term *Rāśigola-sphuṭa*, is in modern astronomy known as 'Reduction to the ecliptic.'

Acyuta's Formula for the correction

Acyuta has enunciated a formula for this correction in his *Sphuṭanirṇaya*, and, in the present context, the *Rāśigolasphuṭānīti* quotes (verse 51) the passage from that work :[11]

पातोनस्य विधोस्तु कोटिभुजयोर्जीवे मिथस्ताडये-
दन्त्यक्षेपशराहतं वधममुं विक्षेपकोट्या हरेत् ।
लब्धं व्यासदलोद्धृतं हिमकरे स्वर्णं, विपाते विधौ
युग्मायुग्मपदोपगे ; विधुरयं स्पष्टो भगोले भवेत् ॥

"Multiply the tabular cosine (*koṭijyā*) and sine (*bhujājyā*) of Moon-minus-Node, and the product by the tabular versine (*śara*) of the maximum latitude (*antya-kṣepa*) of the Moon. Divide this by the tabular cosine of the latitude at the particular moment and the quotient is to be divided again by the tabular radius (*vyāsa-dala*). The result (will give the correction for longitude which) is to be added to or subtracted from the Moon's longitude, as Moon-minus-Node is in an even or odd quadrant, respectively. This Moon will be the True Moon as measured on the ecliptic."

This correction can be extened to the case of all planets.

Mathematical proof for the Formula

Thus, if F is the longitudinal difference between the Node and the Planet, w the maximum *Vikṣepa*, λ the actual *Vikṣepa*, and the correction required is k,

$$\text{Bhujājyā } k = \frac{\text{Bhujājyā F} \times \text{Koṭijyā F} \times \text{Śara } w}{\text{Koṭijyā } \lambda \times \text{Trijyā}}$$

$$\textit{i.e.}, \text{ Rsin } k = \frac{\text{Rsin F} \times \text{R cos F} \times \text{Rversine } w}{\text{Rcos } \lambda \times \text{R}}, \text{ where R} = \text{Trijyā}$$

11. *Sphuṭanirṇaya*, IV. 2, edn. *ibid.*, p. 25.

$$i.e., \text{ Sin } k=\frac{R^3 \sin F \times \cos F\,(1-\cos w)}{R^3 \cos \lambda}$$

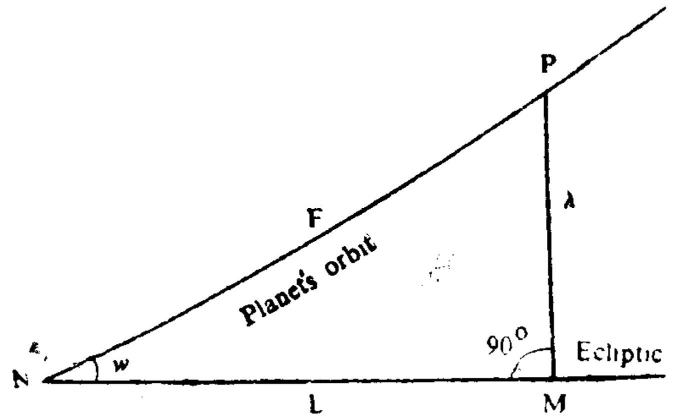
$$=\frac{\sin F.\cos F\,(1-\cos w)}{\cos \lambda}$$

Since k is very small, sin k might be taken to be equal to k.

$$\therefore\ k=\frac{\sin F.\cos F\,(1-\cos w)}{\cos \lambda}$$

Verification of Acyuta's Formula

The exactitude of Acyuta's correction can be verified by the application of Napier's rules (A.D. 1550-1617) for a right-angled spherical triangle.



N=Node

P=Planet

F=NP=Longitudinal difference between the Node and the Planet along its orbit

L=NM=Longitudinal difference between the Node and the Planet along the ecliptic

λ=PM=Latitude of the Planet at the moment, *i.e., tatkāla-vikṣepa*

w=Angle between the ecliptic and the orbit (*parama-vikṣepa*)

From Napier's rule for $\triangle$NMP,

$$\cos w=\cos F.\tan\ L=\frac{\cos F.\sin L}{\sin F.\cos L}$$

$$\therefore\ 1-\cos w = 1-\frac{\cos F.\ \sin L}{\sin F.\ \cos L}$$

$$= \frac{\sin F.\ \cos L - \cos F.\ \sin L}{\sin F.\ \cos L}$$

$$= \frac{\sin (F-L)}{\sin F.\ \cos L}$$

$$\therefore\ \sin (F-L) = \sin F.\ \cos L.\ (1-\cos w)$$

$$= \frac{\sin F.\ \cos F}{\cos \lambda}.\ (1-\cos w)$$

(since $\cos F = \cos \lambda.\ \cos L$)

If k is the correction to be applied to F to obtain L, then

$$F-L=k$$

$$\therefore\ \sin k = \frac{\sin F.\ \cos F}{\cos \lambda} (1-\cos w)$$

This is exactly the formula for the correction enunciated by Acyuta.

Taking the value accepted by Acyuta[12] for the maximum latitude of the Moon, *viz.*, 288′, the correction for Moon will be :

$$k = \frac{\sin F.\ \cos F.\ (1-\cos 288')}{\cos \lambda}$$

$$= \frac{\sin F.\ \cos F}{\cos \lambda} \times 0{\cdot}0035$$

Simplified formula for the Moon

The text further adds (verse 53) that Acyuta has given this correction in a simplified form in his *Kriyākrama*. *Cf.* :

अयमेव हि संस्कारो लघूकृत्य 'क्रियाक्रमे' ।
तेनैव 'त्तेपवर्वीरांशं कुर्याद्' इत्यादिनेरितः ॥

---

12. *Cf.* क्षेपाः शशाङ्कात् परमाः क्रमेण नागाहिदस्राः स्वरबाणनन्दाः ।
खवेदरामाः खकुलाचलाश्च बाणाद्रिचन्द्राः स्वरभास्कराश्च ॥
(*Sphuṭanirṇaya* I. 15)

The maximum *vikṣepa* for the Moon is नाग-अहि-दस्र, *i.e.*, 288, *kalās* or minutes.

The reference is to his *Uparāga-kriyākrama*, ch. I, verse 42 :

पर्ववत् 'चेपवीरांशं कुर्या' च्चन्द्रे स चन्द्रमाः ।
परमग्रासकाले स्वे स्यात् पर्वान्ते रविग्रहे ॥

where a correction of one twenty-fourth of the *Vikṣepa* at the particular moment (*tatkāla-vikṣepa*) is recommended to be applied to the Moon in the calculation of eclipses. This would give the result :

$$k=\frac{\text{Vikṣepa}}{\text{Vīra}},\ i.e.\ \frac{\lambda}{24}$$

Proof for the Simplified formula

This can be derived as follows. As shown above, for the Moon

$$k=\frac{\sin F.\ \cos F.}{\cos \lambda}\ 0.0035$$

$$=\sin F.\ 0.0035$$ (since cos F and cos λ can each be taken to be 1, for at the time of an eclipse F is very near 0° or 180° and λ is still smaller.)

Now, sine latitude at any moment is equal to the sine of the maximum latitude multiplied by the sine of the longitude, *i.e.*,

$$\sin \lambda=\sin w.\ \sin F$$

$$\therefore\quad \sin F=\frac{\sin \lambda}{\sin w}=\frac{\sin \lambda}{\sin 288'}=\frac{\sin \lambda}{\cdot 0837}$$

Substituting this value in the above equation,

$$k=\frac{\sin\lambda}{\cdot 0837}\times \cdot 0035$$

$$=\frac{\sin \lambda}{23{\cdot}91}=\frac{\lambda}{24}$$ (Since λ is very small and taking 23.91 as 24 makes but a negligible difference.)

Identification of the correction elsewhere

The first among Western astronomers to note this correction is the German astronomer Tycho Brahe who lived between 1546 and 1601 and thus was a contemporary of Acyuta (1550-1621).

This correction of reduction to the ecliptic is not mentioned in early Indian astronomy ; and, among the mediaeval astronomers of North India, the first to mention it is Nityānanda of Indraprastha in his *Siddhāntarāja* written in 1639 A.D.[13] It redounds to the credit of Kerala astronomers to have shrewdly discerned this correction and to have derived for it a formula which tallies with modern mathematics.

Chronology of Acyuta's works

A new light on the chronology of Acyuta's works can be had from his reference to his *Sphuṭanirṇaya* and *Uparāga-kriyākrama* in the present work. The first *pāda* of the final verse of the latter work, प्रोक्तः प्रश्रयतो ध्यानात्, gives the Kali day of its completion, *viz.*, 17,14,262,[14] which works out to A.D. 1593. The *Sphuṭanirṇaya* gives the full formula for the reduction to the ecliptic (IV. 2), which the work says he has reduced to a simpler form in the *Uparāga-kriyākarma*, and, so, the *Sphuṭanirṇaya* should have been composed prior to A.D. 1593. This would mean that Acyuta had identified the reduction to the ecliptic and specified his formula for the correction earlier than A.D. 1593.

Acknowledgements

The *Rāśigolasphuṭānīti* issued now is its revised second edition. The first edition of the work had been published more than twenty years ago, in 1955, by the well-known Adyar Library and Research Centre, Madras. The book has long been out of print and the authorities of the Centre gladly permitted the publication of its second edition under the auspices of our Institute. I am deeply grateful to the Centre for the kind permission given in the above regard.

The first edition had been issued on the basis of a single manuscript of the work, thanks to the Govt. Oriental Mss. Library, Madras. The present second edition has the benefit of the use made

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13. *Cf.* Sudhakara Dvivedi, *Gaṇakataraṅgiṇī*, rev. edn., Benares, 1933, p. 101.

14. An old Malayalam commentary on this work (Mss. Trav. Uni. C. 173 E) states : *ī ślokattinte naṭe pādam grantham camaccua tīrnna Kalikkoṭṭa nāḷ ākayum uṇṭu*" ('The first *pāda* of this verse represents also the Kali date of the completion of this work').

in it of another manuscript discovered recently from the Kerala University Oriental Research Institute and Mss. Library, Trivandrum. Also, this second manuscript was of special importance since it contained a disquisition on the Reduction to the ecliptic, which is included in the present edition as Appendix I. I am extremely thankful to Dr. K. Raghavan Pillai, Director of the Institute, for making available to me the said manuscript for use in this edition.

I take this occasion to remember again with thanks, the advice rendered and suggestions given, at the time of the preparation of the first edition of the work, by Prof. T.S. Kuppanna Sastri, formerly of the Presidency College, Madras, and the late Shri Rama Varma Maru Thampurān of the scholarly royal house of Cochin.

My thanks are due in full measure also to the V.V.R.I. Press, Hoshiarpur, for the efficient printing and attractive get-up of this publication.

K. V. SARMA

Hoshiarpur,
1. 1. 1977

राशिगोलस्फुटानीतिः

[ग्रहणबीजम्]

[1]इन्दुमार्गतिरश्चीनं द्विस्पृक्सूत्रं भवेद् यदा ।
तदैव परमासत्तिर्ग्रहणे सोमसूर्ययोः ॥ १ ॥

मध्यकाले तु न तथा द्विस्पृक्सूत्रस्य संस्थितिः ।
परमग्रासकालोऽतो भिद्यते मध्यकालतः ॥ २ ॥

TRUE LONGITUDE COMPUTATION ON THE SPHERE OF ZODIAC

(Essence of an eclipse)

1. In an eclipse,[2] the maximum nearness of the Sun and the Moon occurs when the straight line joining the centres of the two (*dvi-spṛk-sūtra*) is perpendicular to the Moon's orbit.

2. At the moment of conjunction or opposition [of the Sun and the Moon] (*madhyakāla*[3] or *sphuṭa-parvānta*), the line joining the centres is not so, (*i.e.*, not perpendicular to the Moon's orbit). Consequently,

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1. Both A and B begin with the words हरिः श्रीः गणपतये नमः । B adds also अविघ्नमस्तु ।

2. The expression 'in an eclipse' (*grahaṇe*) presupposes that the centres of the Sun and the Moon in their respective orbits are very near the Node, so that the small arcs from the Node to the centres may be taken as straight lines. Thus, the Node, the Sun and the Moon may be taken as the vertices of a triangle. Then the least distance of a point to a straight line is the perpendicular from that point to the straight line.

3. In Indian astronomy, by *madhyakāla* is meant the *sphuṭa-parvānta* and not, as it would seem from the term, the moment of the middle of the eclipse. *Cf.*, *Sūryasiddhānta*, IV. 16 :

स्फुटतिथ्यवसाने तु मध्यग्रहणमादिशेत् ।

[पर्वान्ते पक्षद्वयम्]

अर्कमार्गतिरश्चीनां रेखां प्राप्नोति चन्द्रमाः ।
यदा, तदा स्फुटैक्यं स्याद्, इति केचन सूरयः ॥ ३ ॥

पाताद् यावतिथे भागे क्रान्तिवृत्ते रविर्भवेत् ।
विक्षेपमण्डले चन्द्रः पातात् तावतिथेऽन्तरे ॥ ४ ॥

यदा भवेत्, तदैव स्यात् पर्वान्त इति केचन ।
अर्कमार्गतिरश्चीनसूत्रात् पातानुसारतः ॥ ५ ॥

प्राग्वा पश्चाच्च भवति वर्त्मसाम्यं,[4] ततोऽपि च ।
पातासन्नप्रदेशे स्यात् सन्निकर्षः परस्तयोः ॥ ६ ॥

the moment of maximum eclipse is different from the moment oi conjunction or opposition.

(Two views on Conjunction)

3. Some scholars are of opinion that the True longitudes (*sphuṭa*) [of the Sun and the Moon] are equal when the Moon reaches the perpendicular drawn from the Sun's path (*viz.*, the ecliptic) [to cut the Moon's orbit].

4-5*a*. Others, however say that moment of conjunction (*parvānta*)[5] occurs only when the Moon in its orbit (*vikṣepa-maṇḍala*) is as distant in degrees (*bhāga*) from the Node (*pāta*) as the Sun is in its orbit.

5*b*-6. This point of equality in distance (*vartma-sāmya*) on the Moon's orbit will fall either to the East or West of the perpendicular drawn to the Sun's path according as to whether the (proximate) Node is to its East or its West. The point of closest proximity lies further from the point of equality to the side where the node lies.

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4. B. कालसाम्यं ।

5. *Parvānta* really applies to both the moments of conjunction and opposition, but for the sake of facility of expression, it is translated by 'conjunction' alone (which is the case in solar eclipses), here as also below.

व्यहीन्दावोजपदगे पातः पृष्ठगतस्तयोः ।
पुरोगतो युग्मपदे ; तस्मान्मध्याख्यकालतः ॥ ७ ॥

परमग्रासकालोऽयं प्राक्पश्चाच्च भवेत् क्रमात् ।
आसत्तिकालः पर्वान्ताद् भिन्नः पक्षद्वयेऽप्यतः ॥ ८ ॥

भेदस्य तारतम्ये हि केवलं कलहो भवेत् ।
विविच्य नोक्तो भेदोऽयं यद्यप्यार्यभटादिभिः ॥ ९ ॥

तथापि युक्तिसिद्धत्वात् स्वीकृतो ह्यच्युतादिभिः ।

[पर्वान्तनिर्णयः—प्रथमः पक्षः]

मध्यकाले ह्यर्कबिम्बात् स्फुटक्षेपान्तरे विधुः ॥ १० ॥

7-8*a*. If Moon-minus-Node (*vyahīndu*) is in an odd quadrant, the Node will be behind the two, and if it be in an even quadrant the Node will be in front of them. And therefore[6] the moment of maximum eclipse will, respectively, be before or after the moment of conjunction.

8*b*-9*a*. Thus according to both views, the moment of maximum eclipse differs from the moment of conjunction. A dispute can therefore occur only in the estimation of this difference.

9*b*-10*a*. Although this distinction (between the moments of maximum eclipse and the so-called *madhyakāla* or *parvānta*) has not been expressly distinguished by Āryabhaṭa and others, it is recognized by Acyuta and others, since it is obvious by inference.

(Determination of Conjunction : First view)

10*b*-11. At the moment of conjunction, the angular distance of the Moon from the Sun is equal to its latitude corrected for parallax

6. This follows from the fact that, when nearest to the Sun, the Moon's distance from the Node must be less than the Sun's distance from the Node, the former being the hypotenuse of the right-angled triangle formed ; and it is more so from the perpendicular, which is farther away on the Moon's orbit.

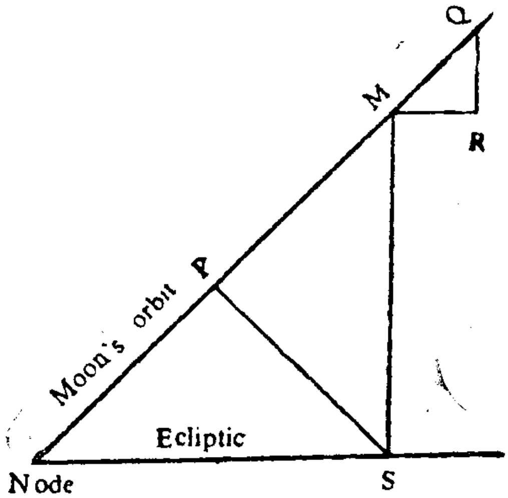
ततः प्रागथवा पश्चादर्कासत्तिर्भवेदिति ।
ज्ञातुं तत्कालसरणिर्विज्ञेया शीतदीधितेः ॥ ११ ॥

विधोस्तत्कालसरणिः कथं ज्ञेयेति चेच्छृणु ।
द्युषष्ट्यंशजभूपृष्ठस्फुटगत्यन्तरं भुजम् ॥ १२ ॥

दिनषष्ट्यंशजस्पष्टक्षेपखण्डः शराभिधः ।
तयोर्वर्गैक्यमूलं स्यात् तत्कालसरणिर्विधोः ॥ १३ ॥

(*Sphuṭa-vikṣepa*). In order to know where the point of maximum nearness to the Sun will occur, to the East or West of [the moment of conjunction], it is necessary to scan the path of the Moon at the moment.

12*a*. If you desire to know the path of the Moon at that moment, listen. [It can be described as follows] :



12*b*-13. (Let) the (*bhujā*) be one-sixtieth of the difference between the daily motions [of the Sun and the Moon] (*dyu-gatyantara*) as corrected for parallax (*bhūpṛṣṭha-sphuṭa*), (MR) ; and let one-sixtieth part of the variation in latitude (*kṣepa-khaṇḍa*) per day as corrected for parallax (*spaṣṭa*) be what is called the 'altitude'[7] (*śara*, the other

7. Though the term 'altitude' is more comprehensive, for the sake of convenience, it is used here to translate the 'altitude of a right-angled triangle' (*śara* or *koṭi*).

अर्कमार्गानुसारी स्याद् बाहुस्तद्व्यस्तदिक् शरः ।
चन्द्रमार्गात्मकः कर्णः प्रमाणक्षेत्रमीदृशम् ॥ १४ ॥

मध्यक्षेपः श्रुतिर्बाहुः परमासत्तिकालजम् ।
बिम्बान्तरं, चन्द्रमार्गे तयोरग्रान्तरं शरः ॥ १५ ॥

इच्छाक्षेत्रमिदं; तत्र ज्ञातेन श्रवणेन हि ।
अज्ञातौ दोःशरौ नेयावनुपातेन ; तद्यथा ॥ १६ ॥

[8]प्रमाणक्षेत्रकर्णस्य यद्येतौ बाहुसायकौ ।
तदेच्छाक्षेत्रकर्णस्य कौ स्तो बाहुशराविति ॥ १७ ॥

side of the right-angled triangle), (QR). Then the root of the sum of their squares (MQ) will give the Moon's path for that period (*viz.* one *nāḍikā*).

14. The base [of the right-angled triangle so formed] is parallel to the Sun's path, the altitude perpendicular to it and the hypotenuse along the orbit of the Moon. Thus is established the antecedent triangle (*pramāṇa-kṣetra*) (MRQ) [where the values of all the sides are known].

15-16*a*. The latitude at the moment of conjunction (*madhya-kṣepa*) (SM) is the hypotenuse, the line joining [the centres of] the orbs [of the Sun and the Moon] at the moment of maximum eclipse (SP), the base, and the line along the Moon's orbit joining the ends of the above two lines (PM), altitude : thus is the consequent triangle (*icchā-kṣetra*) (SPM) established.

16. Here, [in this consequent triangle], since the hypotenuse, [which is the latitude at the moment of conjunction], is known, the base and altitude can be derived by proportion [with the antecedent triangle]. This is how it is :

17. If such are the base and altitude of the antecedent triangle, what would be the base and altitude of the consequent triangle ? (By

8. A. defective. In place of the entire verse, it reads only : प्रमाणक्षेत्रकर्णस्य कौ बाहुशराविति ।

इच्छाक्षेत्रगतौ स्यातां बाहुबाणौ ; तयोः शरः ।
गत्यन्तरात्मको ज्ञेयो यतोऽसौ चन्द्रमार्गगः ॥ १८ ॥

दिनषष्ट्यंशसम्बन्धिस्फुटगत्यन्तरात्मना ।
प्रमाणक्षेत्रकर्णेन नाडिकैका भवेद् यदि ।
तदेच्छाक्षेत्रबाणे[9] कः काल इत्यनुपाततः[10] ॥ १९ ॥

परमग्रासकालस्य भेदः स्यान्मध्यकालतः ।
द्विःकृत्वो हरणं कार्यं कर्णेनैवं यतस्ततः ॥ २० ॥

मध्यक्षेपाच्छरहतात् कर्णकृत्याप्तनाडिकाः ।

means of this argument will be derived the base and altitude of the consequent triangle :

$$\left(SP=\frac{SM.\ MR}{MQ};\ MP=\frac{SM.\ QR}{MQ}\right).$$

18. Of these two, the altitude, since it lies along the Moon's orbit, should be understood to have its value in terms of the relative motions (*gaty-antara-ātmaka*) [per *nāḍikā* projected upon the Moon's orbit].

19-20*a*. And if the hypotenuse of the antecedent triangle (MQ), which represents the relative motions [of the Sun and the Moon] for one-sixtieth of a day, is one *nāḍikā*, what time will the altitude of the consequent triangle represent ? This proportion will give the time between the moments of maximum eclipse and conjunction, *i.e.* :

$$\left(\frac{MP}{MQ}=\frac{SM.\ QR}{MQ.\ MQ}\right)$$

20*b*-21*a*. Since, [in the above calculation], division with the hypotenuse [MQ of the antecedent triangle] is to be done twice, the resultant *nāḍikās* [are] obtained by multiplying the latitude at conjunction by the altitude, and dividing the product by the square of the hypotenuse [of the antecedent triangle], *i.e.*, $\left(\frac{SM.\ QR}{MQ^2}\right)$

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9. A.B. have an extra न here, बाणेन.

10. B. इत्यतियुक्तित: ।

स्वर्णं कुर्यान्मध्यकाले तयोर्दिग्भेदसाम्यतः ॥ २१ ॥

परमग्रासकालोऽयं, मध्यक्षेपाद् भुजाहतात् ।

कर्णाप्तो बिम्बभेदः स्यात् परमग्रासकालजः ॥ २२ ॥

तदूनं बिम्बयोगार्धं भवेद् ग्रासप्रमा परा[11] ।

विधोरर्ककलाप्राप्तिः पर्वान्त इति यन्मतम् ॥ २३ ॥

तन्मते प्रोक्तमखिलं युज्यते नात्र संशयः ।

21*b*-22*a*. [These *nāḍikās*] are to be added to, or subtracted from, the moment of conjunction, according as to whether the directions (North or South) of the two, (*viz.*, the latitude and altitude), are different or the same, respectively.[12] This is the moment of maximum eclipse.

22. Multiply the latitude at conjunction (SM) by the base (MR) and divide by the [antecedent] hypotenuse (MQ) ; the result will be the distance between [the centres of] the orbs [of the Sun and the Moon] at the moment of maximum eclipse, *i.e.*, $\left(SP = \frac{SM \cdot MR}{MQ}\right)$

23*a*. This, subtracted from half the sum of the angular diameters (*bimba*) [of the Sun and the Moon], will give the maximum eclipse.

23*b*-24*a*. All that is said here accords, in fact, only with the school that says that the moment of conjunction is when the Moon

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11. A. परम् ।

12. This follows from the following consideration : When the Moon at conjunction is in advance of the Node, this correction has to be deducted because the maximum-eclipse-position is behind the Moon ; under this condition the *vikṣepa* and the *śara* are both North or both South, *i.e.*, there is sameness of direction, (*dik-sāmya*). Hence the rule : '*Dik-sāmye ṛṇa*', 'Deduction when the directions are the same'. When the Moon at conjunction is behind the Node, the maximum-eclipse-point is in advance of the Moon and hence the correction has to be added. Under this condition, the *vikṣepa* and *śara* are of different directions, one North and the other South. Hence the rule *'Dig-bhede dhanam'*, 'Addition when the directions are different'.

[द्वितीयपक्षखण्डनम्]

वर्त्मसाम्यं हि पर्वान्त इति पक्षे विधोर्गतिः ॥ २४ ॥

क्षेपवृत्तानुसारी स्यात् ततोऽस्या बाहुता कथम् ।
तर्हि गत्यन्तरांशस्य बाहुत्वं नेह कल्प्यते ॥ २५ ॥

किन्तु कर्णत्वमिति चेद्, भवत्वेवं शशिग्रहे ।
रविग्रहे तु कर्णत्वमपि तस्या न युज्यते ॥ २६ ॥

यतो नतिवशादिन्दोर्वर्त्म भिन्नं प्रतिक्षणम् ।
अनुगत्यन्तरांशस्य बाहुत्वं भास्वतो ग्रहे ॥ २७ ॥

बाणत्वं नतिखण्डस्य पक्षेऽस्मिन् यदि[13] कल्प्यते ।

attains the same [number of] minutes (*kalās*) as the Sun, [both measured along the ecliptic].

(**Refutation of the Second view**)

24*b*. But, according to the school which says that the moment of conjunction is equality of distance [from the node], [the calculations as described above are impossible for the several reasons set out below] :

25*a*. (i) [Firstly], how can this, (*viz*, the relative motion per *naḍika*, MR), be taken as the base in view of the fact that the motion of the Moon is [measured] along its own orbit ?

25*b*-27*a*. (ii) It may be argued that the relative motion per *nāḍikā* (*gaty-antara-aṁśa*) is not taken as the base, but only as the hypotenuse. (But it has to be noted that) this might be so in the case of the Lunar eclipse ; but, in the case of the Solar eclipse, it cannot be taken as the hypotenuse, since the path of the Moon is changing every moment owing to parallax in latitude (*nati*).

27*b*-28. (iii) If, according to this school and with reference to the Solar eclipse, it is argued : Let the relative motion [along the

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13. A. नहि for यदि ।

तदा[14] तयोर्वर्गयोगमूलस्यात्रेन्दुमार्गता ॥ २८ ॥

इति चेन्न, यतो नात्र तयोर्दोःकोटिरूपता ।

तथा हि नतिखण्डः स्याद्व्यस्तदिक्कोऽर्कमार्गतः ॥ २९ ॥

गत्यन्तरांशकश्चास्मिन् पक्षे स्यादिन्दुमार्गतः[15] ।

अतोऽनयोर्मिथो न स्याद्दोःकोटित्वमिति स्थितम् ॥ ३० ॥

किञ्च लम्बनखण्डेन घटिकाकालजेन च ।

ऊनितो गतिभेदांशो बाहुर्ज्ञेयः पुरोदितः ॥ ३१ ॥

तत्र लम्बनखण्डोऽयं रविमार्गगतो भवेत् ।

गत्यन्तरांशकश्चात्र चन्द्रमार्गगतो यतः ॥ ३२ ॥

ततोऽनयोर्वियोगोऽपि वस्तुतस्तु न युज्यते ।

Moon's path] (*anu-gaty-antara-aṁśa*) be taken as the base, and the variation in latitude corrected for parallax (*nati-khaṇḍa*) as the altitude, then the root of the sum of their squares will give the path of the Moon.

29-30. [The answer is :] No, because in this case they do not form the base and altitude [of a right-angled triangle] ; for, the latitudinal variation is perpendicular to the Sun's path and the longitudinal variation is [measured], according to this school, along the Moon's path and hence there cannot be any base-altitude relationship between them.

31. (iv) Further, [if it is said that] the base taken above is the relative variation in longitude (*gati-bheda-aṁśa*) minus the variation in parallax in longitude (*lambana-khaṇḍa*) per *nāḍikā* (*ghaṭikā-kālaja*) ;

32-33*a*. [this is improper]; for, here, the variation in parallax in longitude is measured along the Sun's path ; but the relative variation in longitude is (measured) along the Moon's path ; (these two are different) ; hence the subtraction of one from the other is, in fact, not possible.

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14. A. तथा for तदा.

15. B. मार्गग;

एतद्दोषनिरासार्थं यद्यत्र नतिलम्बने ॥ ३३ ॥
तयोः खण्डौ च नीयन्ते भास्करोक्तेन मार्गतः[16] ।
तर्हि लम्बनखण्डस्य गत्यन्तरलवेषु हि ॥ ३४ ॥
युक्तैव संस्कृतिः, किन्तु विक्षेपनतिखण्डयोः ।
मिथो योगो वियोगो वा नोपपन्नो भवेत् तदा ॥ ३५ ॥
यतो नतिः क्षेपवृत्ततिरश्चीनैव तन्मते ।
क्रान्तिवृत्ततिरश्चीनो विक्षेपः सर्वसम्मतः[17] ॥ ३६ ॥
एवं ह्युभयतःपाशारज्जुरत्रापतिष्यति ।
किञ्च गत्योर्वियोगोऽपि पक्षेऽस्मिन् नैव युक्तिमान्[18] ॥ ३७ ॥
भिन्नमार्गगतत्वस्य तयोरप्यविशेषतः ।

33*b*-34*a*. (v) If however, in order to remove this objection, the parallaxes in latitude (*nati*) and longitude (*lambana*) and their variations (*khaṇḍas*) be calculated according to the method prescribed by Bhāskara,

34*b*-36. then, the rectification (*saṁskāra*, addition or subtraction) of the variation in longitude by the variation in parallax in longitude is permissible ; but addition or subtraction between variations in latitude (*vikṣepa-khaṇḍa*) and variation in parallax in latitude (*nati-khaṇḍa*) will not be possible, for, according to Bhāskara, the parallax in latitude is [measured] perpendicularly to the Moon's orbit, and the latitude is [measured], according to all, perpendicularly to the ecliptic.

37*a*. Thus, [according to this school], every approach leads us to a dilemma.

37*b*-38*a*. (vi) Again, according to this school, even the subtraction of the velocity of one from the other is not possible because the two are [measured], along different paths.

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16. The reference is to the combination of नति and विक्षेप enunciated by Bhāskara I in his *Mahābhāskarīya*, V. 27-28.

17. A. has a gap here ; it reads विक्षेप.......स्सर्वतः ।

18. B. युक्तिमत् ।

"लग्नोनान्त्येन्दुदोःकोट्यो"[19]रित्यादाविन्दुलग्नयोः ॥ ३८ ॥

वियोगोऽपि न युक्तोऽत्र यतस्तौ भिन्नवृत्तगौ ।
किञ्चात्र "कृतनत्येन्दोः क्षिप्त्यानीतं स्थितेर्दलम् ॥ ३९ ॥

कृत्वा तत्काललम्बं च पर्वान्ते निर्णयस्तयोः"[20] ।
इत्युक्तस्थितिदलस्यानीतिरपि न युज्यते ॥ ४० ॥

यतः स्थितिदलक्षेत्रगतिभेदांशरूपयोः ।
इच्छाप्रमाणयोर्नात्र वस्तुतस्तुल्यरूपता ॥ ४१ ॥

तस्माद्विधोरन्त्यभुक्तिरन्त्य[21]स्फुट इति द्वयम् ।
क्रान्तिवृत्तानुसार्यैव स्वीकर्तव्यं रविग्रहे ॥ ४२ ॥

38*b*-39*a*. (vii) Then again, according to this school, the subtraction between the Moon and the rising point of the ecliptic (*lagna*), as required in the [verse] beginning with, "of the *bhujā* and *koṭi* of Final-Moon-minus-lagna", is also impossible, because the two move in different circles.

39*b*-41. (viii) Now there is the rule : Calculate the half-duration of the eclipse (*sthiter-dala*) from the Moon's latitude as corrected for parallax, (*kṛta-natyā kṣiptyā*) ; calculate also the parallax in longitude (*lamba*) for the times (*tat-kala*) obtained, (*viz*. the beginning and end of the eclipse) ; and thus determine them (?) at conjunction."

The calculation of the half-duration of the eclipse according to this rule is also not possible, since, really, there is no similarity between the fields on which the half-duration and the relative variation in motion are represented, (*viz*., the ecliptic and the Moon's orbit) which form, respectively, the consequent (*icchā*) and the antecedent (*pramāṇa*).

42. Therefore in the Solar eclipse, the two, the rectified velocity of the Moon (*antya*- or *saṁskṛta-bhukti*) and latitude corrected for

19. *Uparāga-kriyākrama*, III. 28 ff.

20. *Uparāga-kriyākrama*, III. 41.

21. A. has a gap in the place of रन्त्य.

[22]तथा च सूर्यशशिनोर्गत्योश्च स्फुटयोरपि ।
विश्लेषो युज्यते तद्वद् भुजाद्यानीतिरेव च ॥ ४३ ॥

क्रियाक्रमे त्वन्त्यभुक्तिरपि विक्षेपवृत्तगा ।
गृह्यतेऽतो भुजादीनामानीतिर्नातिसुन्दरा ॥ ४४ ॥

राशिगोलस्फुटैक्यं हि यदा स्यादर्कचन्द्रयोः ।
स एव कालः पर्वान्तो ग्राह्यः सूर्यग्रहे सदा ॥ ४५ ॥

अन्यथा लम्बसंस्कारः पर्वान्ते नैव युज्यते ।
क्रान्तिवृत्तकलारूपाः यतो लम्बनलिप्तिकाः ॥ ४६ ॥

[राशिगोलस्फुटसंस्कारः]

इन्द्वादीनामपि गतिः क्रान्तिवृत्तानुसारिणी[23] ।

parallax, have to be measured only in relation to the ecliptic, [the former along it and the latter perpendicular to it.]

43. Again, it would be proper to take the differences between the velocities of the Sun and the Moon and that between their rectified latitudes and so also in the matter of the determination of the sines etc.

44. In the *Kriyākrama*, the rectified velocity too is measured along the (planet's) orbit, and hence the derivation of the sines etc. is not quite accurate.

45. In the solar eclipse, that moment alone is to be taken as the moment of conjunction when the rectified latitudes of the Sun and the Moon on the celestial sphere (of which the ecliptic is a great circle) are identical.

46. Otherwise, corrections for parallax would not be correct at the moment of conjunction, for the seconds of parallax (*lambana-liptāḥ*) are in terms of the seconds of the circle of the ecliptic.

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22. A. Omits. verses 43-46.

23. B. गतिः गृह्यते राशिगोलगा ।

अतो न क्षेपतो भेदः स्फुटस्यापीति यन्मतम्[24] ॥ ४७ ॥
समलिप्ताकाल एव पर्वान्तस्तन्मते भवेत् ।
चन्द्रादयः क्षेपवृत्ते भ्रमन्ति सततं यतः ॥ ४८ ॥

ततः स्फुटोऽपि तेषां स्यात् स्वतोऽपि क्षेपवृत्तगः ।
इति पक्षे हि पर्वान्तः साम्यकालो न केवलम् ॥ ४९ ॥

[26]अस्मिन् पक्षे हि चन्द्रस्य राशिगोलस्फुटाप्तये ।

(Correction for Reduction to the Ecliptic)[25]

47-48*a*. Now, according to the view of those who consider that the true motions of the Moon and the other [planets] are given [by the *Śāstrakāras*] along the ecliptic, and hence their true longitudes are not vitiated by their orbital motion (*kṣepataḥ* means *kṣepa-vṛtta-gamanataḥ*), the moment of equality in degrees will itself give the moment of conjunction (*parvānta*).

49*b*-50. On the other hand, according to the view that since the Moon and other [planets] always move on [their own] orbits (*kṣepa-vṛtta*)

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24. A. यन्मतो: B स्फुटस्येति हि यन्मतम् ।

25. Having established that measurement of longitude and latitude are to be made only with reference to the ecliptic, the former along it and the latter perpendicular to it, the text takes up another question, whether a correction is necessary to the orbital longitude of the Moon in view of the fact that it actually moves along its orbit and its longitude is measured on the ecliptic. On this question there might be a school who would consider that the rules for calculating the longitude given by the *Śāstrakāras* include this correction ; for them no more correction would be necessary. But if it is be viewed that the basic textbooks (*Śāstras*) give the true-longitude (*sphuṭa*) only along the respective orbits, a correction called the 'Reduction to the Ecliptic' is necessary, which might be expressed by the term *Rāśigolasphuṭānīti*, in a restricted sense. Obviously, Acyuta is one who deems the correction necessary.

26. B. reads the verse as :

अस्मिन् पक्षे हि चन्द्रस्य स्फुटीकरणतः परम् ।
राशिगोलस्फुटाप्त्यै हि कार्यं यत्नान्तरं बुधैः ॥

स्फुटीकरणतः पश्चात् कार्यं यत्नान्तरं यतः ॥ ५० ॥
तत्प्रकारश्चाच्युतेन कीर्तितः स्फुटनिर्णये[27] ।
"पातोनस्य विधोस्तु कोटिभुजयोर्जीवे मिथस्ताडये-
दन्त्यक्षेपशराहतं वधममुं विक्षेपकोट्या हरेत् ।
[28]लब्धं व्यासदलोद्धृतं हिमकरे स्वर्णं, विपाते विधौ
युग्मायुग्मपदोपगे ; विधुरयं स्पष्टो भगोले भवेत्" ॥ ५१ ॥
[29]इत्यत्र वासना ज्ञेया कलास्वन्तरवद् बुधैः ॥ ५२ ॥

and hence their true longitudes (*sphuṭa*) are [measured] on their orbits, the moment of conjunction is not equality in degrees [measured on the ecliptic].

50-52. It is because, according to this view, a further correction has to be applied to the true longitude [as measured on its orbit] to obtain the true longitude as measured on the ecliptic (*rāśigola-sphuṭa-āptaye*), that a method to this effect has been enunciated by Acyuta in the *Sphuṭanirṇaya*.

"Multiply the tabular cosine (*koṭijyā*) and sine (*bhujājyā*) of Moon-minus-Node and the product by the tabular versine (*śara*) of the maximum latitude (*antya-kṣepa*) of the Moon. Divide this by the tabular cosine of the latitude at the particular moment and the quotient is to be divided again by the tabular radius (*vyāsa-dala*). The result [will give the correction for longitude which] is to be added to, or subtracted from, the moon's longitude, as Moon-minus-Node is in an even or an odd quadrant, respectively. The True-Moon measured on the ecliptic is thus got."

The proof for this may be understood by wise men learned in the (nuances of astronomical) science (*kalāsu*).

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27. The verse next quoted is *Sphuṭanirṇaya*, IV. 2. See Introduction, pp. 12-14, for the trigonometrical verification of the correction of Reduction to the Ecliptic enunciated here.

28. A.B. read लब्धाद्. The better reading लब्धं is from the original *Sphuṭanirṇaya*.

29. B. omits the further verses, but has a discussion on this verse which is edited below as Appendix I.

अयमेव हि संस्कारो लघूकृत्य क्रियाक्रमे ।
तेनैव "क्षेपवीरांशं कुर्याद्" इत्यादिनेरितः[30] ॥ ५३ ॥

राशिगोलस्फुटानीतिरच्युतेनैवमीरिता[31] ।
क्रान्तिवृत्तगतिश्चैवमानेया गोलवित्तमैः ॥ ५४ ॥

[इत्यच्युतमतानुसारिणी राशिगोलस्फुटानीतिः ॥]

53. This very correction has been enunciated in a simplified form by the same [author] in [his *Uparāga-*]*Kriyākrama* in the words "Apply one twenty-fourth part of the latitude" etc.

54. Thus has been enunciated the "True-longitude Computation on the Sphere of Zodiac" by Acyuta. True longitudes [of planets] on the ecliptic should be calculated by experts in this manner.

[THUS ENDS TRUE-LONGITUDE COMPUTATION
ON THE SPHERE OF ZODIAC
ACCORDING TO ACYUTA]

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30. The reference is Acyuta's *Uparāga-kriyākrama,* ch. I. 41 :

पर्ववत् 'क्षेपवीरांशं कुर्या'च्चन्द्रे स चन्द्रमाः ।
परमग्रासकाले स्वे स्यात् पर्वान्ते रविग्रहे ॥

For a mathematical demonstration of this formula, see above, Introduction, pp. 15-16.

31. A.B. have ईरितम् in the neuter.

APPENDIX I

राशिगोलस्फुटसंस्कारविवेचनम्

DISQUISITION ON REDUCTION TO THE ECLIPTIC

'पातोनस्य विधोस्तु' इत्यादिश्लोकस्य वासना

पातोनस्य विधोस्तु कोटिभुजयोर्जीवे मिथस्ताडयेद्
अन्त्यक्षेपशराहतं वधममुं विक्षेपकोटया हरेत् ।
लब्धं व्यासदलोद्धृतं हिमकरे स्वर्णं, विपाते विधौ
युग्मायुग्मपदोपगे ; विधुरयं स्पष्टो भगोले भवेत् ॥

[1]अत्र वासना प्राणकलान्तरवत् ज्ञेया । कथं पुनः राशिगोलस्फुटगत्यानयनमिति चेत् उच्यते । पातोनेन्दुं द्विगुणीकृत्य ततः कोटिज्यामानीय तया स्फुटगतिं हत्वा क्षेपकोटया हरेत् । तत्राप्तं अन्त्यक्षेपशरेण हत्वा त्रिज्ययाप्तं फलं द्विघ्नस्य पातोनेन्दोः कर्किनक्रादिवशाद् गतौ धनमृणं वा कुर्यात् । तदा इन्दोः क्रान्तिवृत्तस्फुटगतिर्भवति । एवं सामान्येन इन्दोः राशिगोलगतस्फुटगत्योरानयनमुक्तम् ।

उपरागे तु गुणकारभूताया व्यहीन्दुकोटया हारभूतायाः क्षेपकोटयाश्च प्रायेण त्रिज्यातुल्यत्वनियमात् ताभ्यां न किञ्चित् कृत्यमस्ति । अतस्तदानीं अन्त्यक्षेपशरो गुणकारः । स च अच्युतमते प्रायेण द्वादशसंख्यः । तत्र व्यासार्धे द्वादशभिर्हृते सति हारकः स्यात् । स चाक्षरसंख्यया 'सुन्दर' (२८७) इति भवति । तदेवं व्यहीन्दुदोर्ज्या'सुन्दरां'शस्फुटान्तरं गतिः, 'सुन्दरां'शो गत्यन्तरमिति च स्थितम् ।

तत्र यदि विक्षेपात् स्फुटान्तरमानीयते तर्हि विक्षेपस्य व्यहीन्दुदोर्ज्या'रम्यां'शत्वात् 'सुन्दररम्यां'शो हारको ग्राह्यः । स च चतुर्विंशतिसंख्यः ।

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1. The following disquisition occurs in the manuscript of *Rāśigolasphuṭānīti*, No. 755 (G) of the Kerala Univ. Or. Res. Inst. and Mss. Library, Trivandrum, in continuation of the verse पातोनस्य विधोस्तु etc.

एतत्सर्वमभिप्रेत्य हि [अच्युकृते उपराग-]क्रियाक्रमे 'पर्ववत् क्षेपवीरांशं' (I.42), 'युगयुक्पदजात् क्षेपाद् वारांशाप्तं स्वमृणं क्रमात्' (II. 6) इत्याद्युच्यत इति ध्येयम् ।

एतत्स्फुटान्तरसम्बन्धिकालानयने पुनरिदं त्रैराशिकम् — यदि गत्यन्तरांशतुल्याभिः षष्टिर्विनाड्यो लभ्यन्ते तदा 'क्षेपवीरांश'तुल्याभिः कति विनाड्य इति । अत्र विक्षेपस्य षष्टिर्गुणकारः, चतुर्विंशतिर्हारकः । एतौ द्वादशभिरपवर्तितौ क्रमात् पञ्चसंख्यो द्विसंख्यश्च भवतः । तदुक्तं—

युगयुक्पदजात् क्षेपात् पञ्चघ्नाद् द्विघ्नगतिभिदांशाप्ताः ।
विघटीः स्वमृणं कुर्यात् पूर्णान्ते व्यत्ययेन दर्शान्ते ॥

(उपरागक्रियाक्रमः, I. 41)

इति । अत्र हि शशिग्रहे नतिलम्बनयोरभावात् विक्षेपवृत्तरूपैवेन्दोस्तत्काल-सरणिः । ततश्च अर्कबिम्बाक्रान्तक्षेपपार्श्वाख्यवृत्तं यदा चन्द्रः प्राप्नोति तदैव परमग्रासः । स च व्यहीन्दौ युक्पदगे साम्यकालात् प्रोक्तविनाडिकाभिः पश्चात् स्यात् । अयुक्पदगे तु प्राक् ।

सूर्यग्रहणे तु पूर्वोक्तयुक्तिभिः इन्दोरर्ककलाप्राप्तिकाल एव पर्वान्तत्वेन ग्राह्यः । स च व्यहीन्दौ युक्पदगे साम्यकालात् प्राक्, अयुक्पदगे पश्चात् । अत उक्तं—'व्यत्ययेन दर्शान्ते' इति । तस्मात् वर्त्मसाम्यं हि पर्वान्त इति पक्षे (*Cf.* राशिगोल., 4-6) विधोर्गतिः क्षेपवृत्तानुसारी स्यात् । 'ततोऽस्या बाहुता कथम्' (राशिगोल., 25a) इत्यारभ्य क्रियाक्रममते सूर्यग्रहणे यानि दूषणान्युक्तानि तत्सर्वं निराकरणीयमिति यद्याग्रहः तर्हि प्रथमाध्यायान्ते—

सोऽयं संस्कृतशीतांशुराद्योऽन्त्यः समलिप्तिकः ।
तद्गतिर्निजसिन्दूरभागोना च रविग्रहे ॥

इति वक्तव्यं स्यात् । अस्मिंश्च पक्षे विक्षेपानयने—

व्यहीन्दुदोर्ज्या रम्याप्ता लम्बहारकताडिता ।
युद्धार्थाप्ता युता क्षेपो लिप्तात्र्यंशविलिप्तया ॥

(*Cf.*, उपरागक्रियाक्रमः, I. 39)

इति पाठः कार्यः । लम्बनविनाडीसंस्कारे च—

इन्दोर्मध्यगतिघ्न्यः प्राक् लम्बहारविभाजिता ।

(*Cf.*, उपरागक्रियाक्रमः, III. 13)

इति पठनीयम् ।

किञ्च एवं इष्टग्रासानयने 'केवलक्षेपवीरांश'संस्कारो न कार्यः। ततश्च तत्कालदृग्गतेर्भेदहाराप्ता लम्बनलिप्तिकाः कृत्वा इन्दौ तेन तत्तत्काल-भानोः कार्यं स्फुटान्तरम् इत्येव इष्टग्रासविधौ वक्तव्यं स्यात्। चन्द्रग्रहणे तु विक्षेपवृत्तगतगत्योरन्तरमेव ग्राह्यम्। तच्च अर्कगति'सुन्दरां'शयुतकेवलगत्य-न्तरमेव। न चैवं स्थित्यर्धानयनानुपपत्तिः शङ्क्या, स्थित्यर्धकोट्या अपि क्षेपवृत्तगतया एव स्वीकारात्।

ननु इन्दोः स्फुटं द्वयमपि स्वतो विक्षेपवृत्तगतमेव। ततश्चाद्येन्दो-रानीतः क्षेपः क्रान्तिवृत्ततिरश्चीन एव स्यात्।

इष्टाग्रगा त्विह वृतिद्वययोगमूला
दोर्ज्येष्टमण्डलगता खलु कर्णरूपा।
दोर्ज्याग्रकेऽन्यवृतिपार्श्वकयोस्तथैव
स्पृष्टे तु मण्डल इहाभिमतान्तरालम्॥

इति न्यायात्।

एवं च इन्दुमार्गविक्षेपयोर्मिथो दोःकोटित्वाभावात् स्थित्यर्धकोट्या इन्दुमार्गगतत्वं न संभवत्येवेति चेन्मैवम्। न ह्यस्मिन् पक्षे मध्यकालजेन्दुस्फुटा-दानीतविक्षेपेण स्थित्यर्धकोटिरानीयते, येन उक्तदोषः स्यात्। किन्तु मध्य-कालीनबिम्बान्तरेणैव। तच्च इन्दुमार्गविपरीतदिक्कमेवेति न किञ्चिद-समञ्जसम्।

यद्यस्मिन् पक्षेऽपि सम्पर्कार्धमण्डलस्यार्कगत्या चलनात् तत्कालार्कात् पातं विशोध्यानीतक्षेपेणैव स्थित्यर्धमानेयमिति युक्तितः स्थित्यर्धस्याविशेषणं कार्यमेव। तथापि इह मध्यकालक्षेपात् स्पर्शमोक्षजार्कादानीतक्षेपयोर्भेदस्या-ल्पत्वात् ततोऽल्पतर एव स्थित्यर्धभेद इतीह अविशेषाकरणेऽपि न दोषः। एतदेव ह्यभिप्रेत्य **क्रियाक्रमे** चन्द्रग्रहणे स्थित्यर्धस्याविशेषणं नोक्तमिति ध्येयम्।

एवमिष्टग्रासानयनेऽपि यदि तत्कालार्काद् विक्षेप आनीयते तर्हि स्फुटान्तरानयनार्थं चन्द्रे 'क्षेपवीरांश'संस्कारो न कार्यः। ततश्च—

मध्येष्टकालविश्लेषनाडीर्गत्यन्तरांशकैः।
हत्वा तद्वर्गयुक्तेष्टार्कोत्था इष्टक्षेपकृतेः पदम्॥
बिम्बान्तरं तदूनं स्यान्मानैक्यार्धं तदा ग्रहः॥

इत्येवमिष्टग्रासानयनकर्म स्यात्, अथवा 'इष्टघ्नेनेष्टकालजम्' इत्यत्र 'इष्टार्कात्त्विष्टजे ग्रहे' इति वा पाठः कार्यः। **सोमयाज्युक्तपद्येष्वपि** आद्यश्लोके 'सगतीनानयेत् सायनांशान्' इत्यतः पश्चात्—

किन्त्वर्कस्योपरागे विधुचरमगतिः स्वात् सुदारांशहीना,

ग्राह्या चन्द्रोपरागे रविगतिसदरांशान्वितो भुक्तिभेदः ।

इत्युत्तरार्धं पाठ्यम् ।

पुनः 'नाभिघ्ना'दित्यादि द्वितीयश्लोकः । तत्रापि—

चाल्यः सूर्योपरागे चरमहिमकरः सूक्ष्मपर्वान्तकाला-

दाद्येन्दुः साम्यकालादुभयमपि पुनः ग्लौग्रहे साम्यकालात् ।

इत्युत्तरं बोध्यम् ।

ननु ग्रहणगणने 'पर्वान्तः', 'समलिप्ता' चेति द्वौ पदार्थाविव लेखनीयत्वेन प्रसिद्धौ । इह तु 'साम्यकाल'स्यापि लेखनीयत्वात् गौरवमिति चेत् न । यथास्थितपाठेऽपि तस्य लेख्यत्वात् । **क्रियाक्रमे** तु चन्द्रोऽपि स्फुटपर्वान्ते नीत इति यद्यपि साम्यकालेन न प्रयोजनं, तथापि तत्कालार्कस्यापि ज्ञेयत्वेन लेखनेन लाघवातिशयः । प्रत्युत 'क्षेपवीरांश'संस्काररूपं क्रियागौरवमधिकमिति दिक् ।

नन्वेवमपि गतिसंस्कारोऽत्राधिक इति चेत् न । इष्टग्रासे व्यहीन्दुदोः'सुन्दरांश'संस्कारस्येह अकरणीयत्वेन लाघवस्यापि सत्त्वात् । तस्मान्न किञ्चिद् गौरवम् । अत एव हि **लघुभास्करीयव्याख्याने पारमेश्वरे** इन्दुमार्गगतस्थित्यर्धक्षेत्रसिद्ध्यर्थं स्थित्यर्धानयने मध्येष्टविक्षेपयोरेकदिग्गतत्वे अन्तरवर्गं, भिन्नदिक्त्वे तयोर्योगवर्गं च विक्षेपवर्गहीनसम्पर्कार्धकृतौ प्रक्षिप्य मूलीकरणं कार्यमित्युक्तम् (*Cf.* लघुभा. व्याख्या, IV.12, ed., *Anandasrama Skt. Ser.*, No. 128, Poona, 1946, p. 51).

APPENDIX II

INDEX OF AUTHORITIES CITED

APPENDIX III

INDEX OF HALF-VERSES AND PASSAGES CITED

[*Note*: The numbers refer to the verses, their first and second halves being distinguished by 'a' and 'b', respectively. References to pages are prefixed with 'p'.]

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